Principles and Conditions of the Movement of Ground Water. By FRANKLIN HIRAM KING, with a theoretical Investigation of the Motion of Ground Waters, by CHARLES SUMNER SLICHTER. Ext. Nineteenth Ann. Rep. U. S. Geol. Survey, Part II, 1899, pp. lxi + 384.

This important paper bears throughout evidences of the painstaking industry that marks all of Professor King's work. It deals first with general considerations relative to the amount of water stored in the ground in different kinds of rock. For the Dakota sandstone he assigns 15 to 38 feet of water for every 100 feet in thickness of the rock. The water in the Potsdam sandstone of Wisconsin and adjoining states he makes equivalent to an inland submerged sea having a mean depth of 50 to 190 feet of water for the area occupied. In regard to the superficial soils and sands, Professor King gives more detailed data, as this lies in his special field of investigation. A saturated sand carries from 20 to 22 per cent. of its dry weight of water, while the soils and clays range from these values all the way up to 40 and even 50 per cent. of their dry weights. "Since a cubic foot of dry sand weighs from 102 to 110 pounds, while soils, clays and gravels range between this and 79 pounds, we have a ready means of expressing quantitatively the water which is continually stored in this mantle of loose material when it lies below the plane of saturation." In a table of actual determinations where loamy clays and very fine sandy soils are involved, 2 feet of water in 5 feet of soil below the horizon of saturation are shown. When soil does not lie below the plane of saturation it usually contains 75 per cent. of the amount required for full saturation, except during dry times when a surface layer of one to five feet thick falls below this. Even where the plane of saturation lies below a large thickness of soil there is still a large storage capacity for water.

In rocks other than sandstones and soils the percentage is usually very much smaller. Its cumulative magnitude is indicated by the statement that so small an amount of water as 0.0023 of the weight for 5000 feet of the earth's crust is large enough to form a continuous sheet about the globe 30 feet deep. It is believed that water penetrates the crust to depths even exceeding 10,000 feet. Reckoned at 1 per cent., with a specific gravity of rock of 2.65, the amount contained would be a layer 265 feet thick. Of course the amount in the upper horizons is

relatively large and that in the lower very small. An estimate of this kind gives an impression large or small according to the point of view. Regarded by itself, it is large, but compared with the whole hydrosphere it is but a small factor and does not very appreciably add to the oceanic volume. It probably does not amount to so much as the probable error in the estimation of the volume of the ocean and other superficial waters. If the water of hydration be added to it, the statement may not improbably still hold true.

In the treatment of the general movements of the ground water three categories are recognized: (1) Gravitative, (2) thermal, and (3) capillary movements. The oscillations in the flow of springs and artesian wells are illustrated by autographic records and their relations to barometric changes demonstrated. Even the sudden barometric changes accompanying a shower are sometimes sharply recorded. Diurnal changes in temperature are shown to effect the rate of seepage. This is attributed chiefly to the indirect effect of the temperature through the expansion of the gases in the soil. Movements of ground water are ascribed to rock consolidation and crust deformation. Of the 25 to 50 per cent., by volume, of water inclosed in the sediments, when first laid down, a considerable part is forced out as the sediments settle into greater compactness, and finally pass into indurated rock. By an ingenious device on automatic flow from the base to the top of a cylinder of settling sediments was secured against a head of six inches. In the dynamic consolidation of rocks, a still larger per cent. of the inclosed water is forced out. The growth of grains and the filling of pore-spaces is a concurrent source of expulsion of water. Limestones as now taken from the quarries have, as a rule, a pore-space varying from less than 1 per cent. to 7 or 8 per cent. at most; so that the final formation of every 1000 feet of compact limestone means an expulsion of water from these beds during the process of growth and consolidation amounting to not less than one fourth, and possibly as much as one half, of the present volume of the rock.

For the capillary movements of ground water recourse must be had to the paper itself, as the tables cannot be briefly and adequately summarized.

The configuration of the ground water surface is illustrated by contour maps and the flow dependent on this configuration diagrammatically indicated. The changes in the configuration that result from precipitation are shown by tables and by diagrams.

Then follows an account of an elaborate series of investigations of the flow of water through soils, sands, rocks, and other porous media. These are much too extended to be reviewed in detail. They furnish data of prime importance to studies in irrigation, water supply, and various other inquiries that involve the size of grain, the pore-space, and the various elements of resistance to percolation. The industrial as well as the scientific value of these determinations, with which are collated those of others, is obvious.

The value of the experimental study of Professor King is greatly enhanced by the theoretical investigation of the motions of ground water by Professor Slichter. The treatment is mathematical and can be read only by those who are familiar with its elegant language. The excellent illustrations, however, translate some of the more vital parts into the vernacular. Those which relate to the interferences of flows into artesian and other wells are especially instructive.

T. C. C.

Les Lacs Francais. Par ANDRÉ DELEBECQUE. Ouvrage couronné par l'Academie des Sciences. 436 pp., 22 plates, and 153 figures in the text. Accompanied by an atlas of 10 maps. Paris: 1898.

This elaborate work is divided into ten chapters, and a brief outline is here given of the substance of each:

I. *Distribution.*—Most of the lakes of France are in the mountains, the Alps, the Juras, the Vosges, and the Pyrennees; but there are some in the central plateau, some along the coasts, and still others which do not admit of ready classification. The total number of lakes given is between 460 and 470, but many of them are so small that in our own country they would be called ponds.

II. *Depth.*—The second chapter has to do with the depth of the lakes, and the chartings of the soundings.

III. *Description.*—The third chapter is a description of the principal lakes, the description taking account of the depth, the area, the position, etc. Contour maps of the basins of more than forty lakes are given on the plates. Of lakes more than 25 meters deep, there are thirteen in the Alps, eleven in the Juras, two in the Vosges, eight in the central plateau, twelve in the Pyrennees, and one on the coast of the Mediterranean, forty-seven in all. Of lakes more than 1000